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Feasibility Study of QNN-Based Latent Space Generation for Fast Calorimeter Simulation in ATLAS

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The increasing demands on simulation statistics for HL-LHC analyses challenge the scalability of traditional calorimeter simulation within all LHC collaborations. Fast simulation techniques based on machine learning have proven effective, yet further improvements may arise from quantum-inspired models.
In this study we investigate the feasibility of integrating Quantum Neural Network (QNN) components into the ATLAS fast calorimeter simulation framework, to evaluate potential gains in generative performance and generalisation while preserving practical inference times.
We focus on a hybrid pipeline in which a quantum Generative Adversarial Network (qGAN) is employed during training to generate a compressed latent space of calorimeter shower representations. The resulting latent vectors are then passed to classical neural networks for sample inference within the fast simulation framework. This approach allows quantum-inspired elements to be embedded where they can have the largest impact - namely in learning compact, expressive latent manifolds - while retaining full compatibility with ATLAS production workflows.
We report on implementation details, benchmarking against established fast simulation components, and performance metrics including fidelity, stability, and computational cost. Preliminary results indicate that QNN-augmented latent space models are technically feasible within ATLAS software and can achieve competitive performance. This work outlines a realistic roadmap for incorporating quantum-inspired techniques into fast simulation for HL-LHC applications.

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